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(54) **Method for depassivating a lithium battery**

(57) In a method for depassivating a lithium battery, in particular an $LiSO_2$ battery, in an autorecloser, one or more driving pulses are applied to a dummy load from said battery at regular intervals. Pulses may be drawn from the battery at intervals of a few minutes up to one year or so, depending on the application and the environment, in particular the temperature, in which the autorecloser is used. The application of pulses to the dummy load is controlled by a timing means and a microprocessor. The dummy load may consist of an actuator of the autorecloser which is in either a closed or open state such that it is not affected by the driving pulses.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

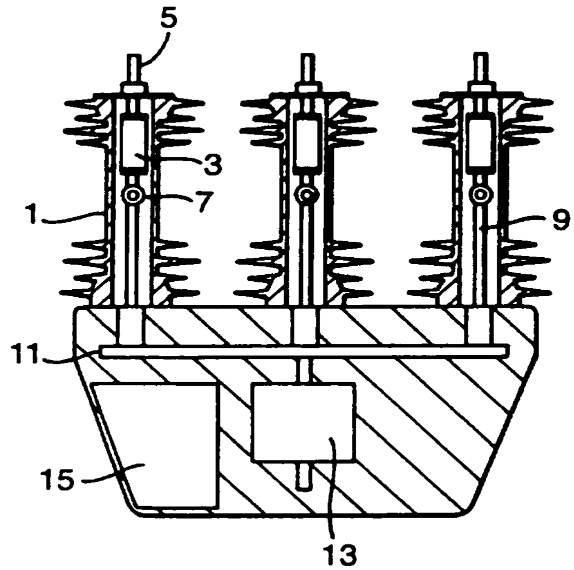
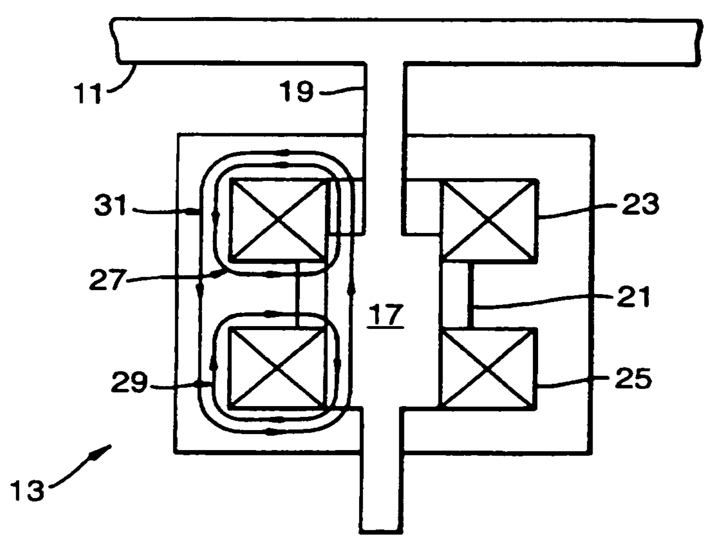


Fig.2.



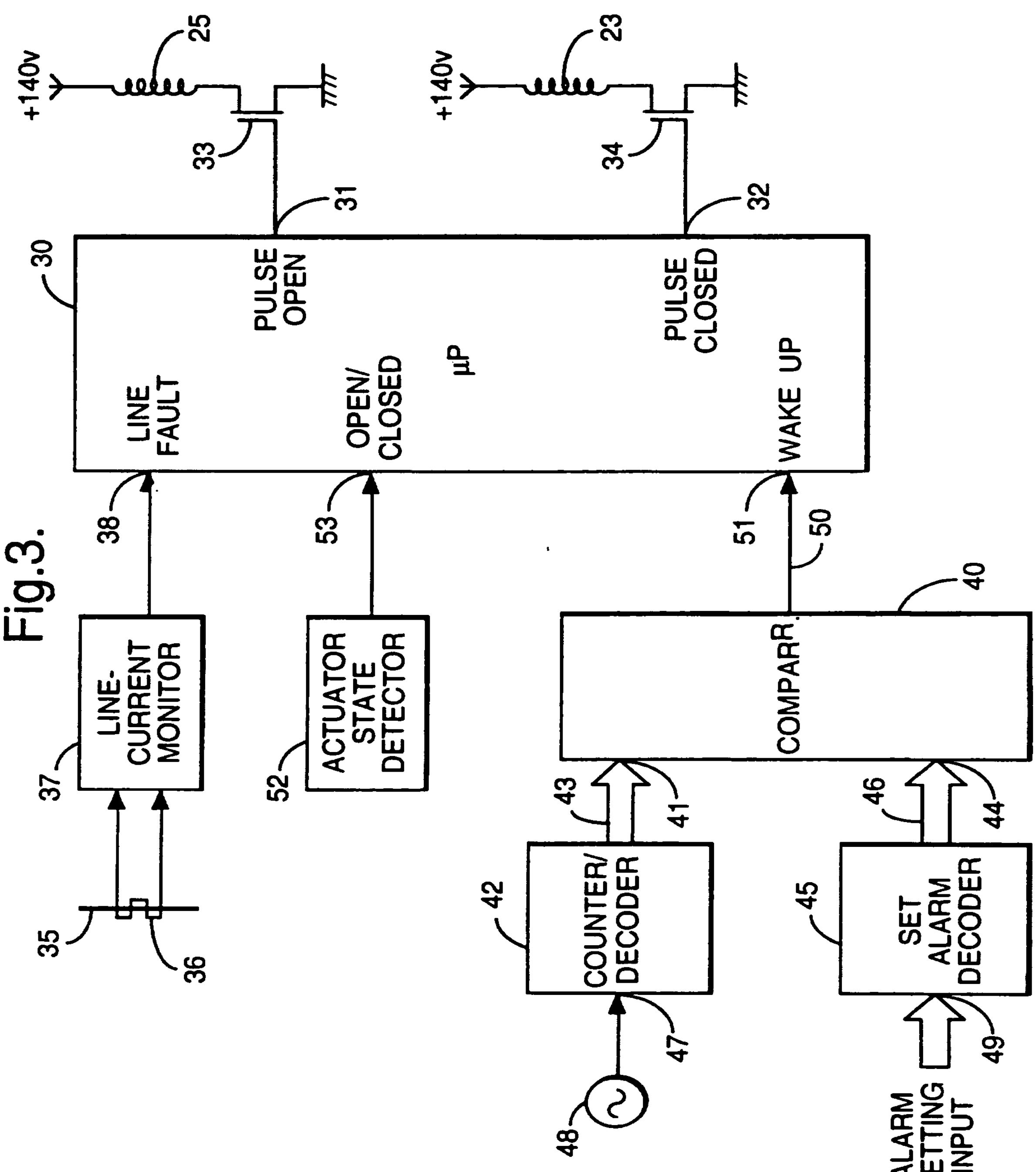
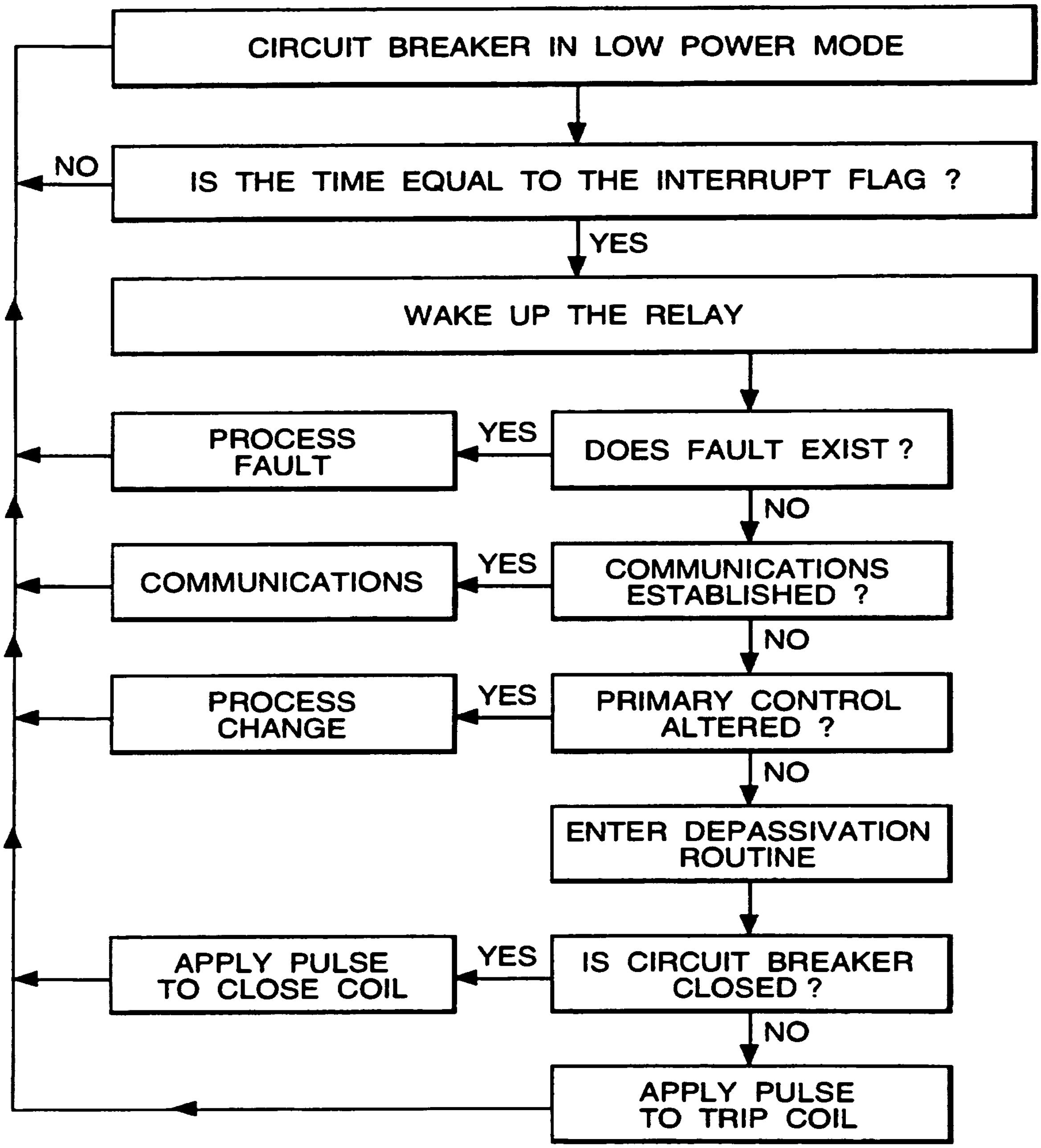

+140v
25
+140v
23
33
34
31
32
30
PULSE OPEN
PULSE CLOSED
μP
LINE FAULT
OPEN/ CLOSED
WAKE UP
38
53
51
50
40
LINE-CURRENT MONITOR
ACTUATOR STATE DETECTOR
COMPARR.
37
52
43
41
46
44
35
36
42
COUNTER/ DECODER
45
SET ALARM DECODER
47
49
48
ALARM SETTING INPUT

Fig.3.

Fig.4.


CIRCUIT BREAKER IN LOW POWER MODE
NO
IS THE TIME EQUAL TO THE INTERRUPT FLAG ?
YES
WAKE UP THE RELAY
PROCESS FAULT
YES
DOES FAULT EXIST ?
NO
COMMUNICATIONS
YES
COMMUNICATIONS ESTABLISHED ?
NO
PROCESS CHANGE
YES
PRIMARY CONTROL ALTERED ?
NO
ENTER DEPASSIVATION ROUTINE
APPLY PULSE TO CLOSE COIL
YES
IS CIRCUIT BREAKER CLOSED ?
NO
APPLY PULSE TO TRIP COIL

METHOD FOR DEPASSIVATING A LITHIUM BATTERY

The invention relates to a method of depassivating a lithium battery in an autorecloser, and especially, but not exclusively, a method of depassivating a lithium sulphur dioxide battery employed in an autorecloser.

When a lithium battery is connected in a system where it is not called upon to operate for long periods, e.g. months or years, one of the battery electrodes acquires a passivation layer which takes time to 'burn off' on switching on after such a period of inactivity. Such a passivation layer can also arise where the battery has been subjected to very low temperatures, eg -25°C to -30°C, for shorter periods.

This passivation layer effectively increases the internal resistance of the battery so that the battery output voltage, and current, are reduced from the rated output for the duration of the 'burn-off' period.

One particular application where this problem arises is in the use of lithium sulphur dioxide ($LiSO_2$) batteries in protection apparatus for electric power systems. In this case a passivation layer of lithium dithionite forms on the anode.

The use of $LiSO_2$ batteries for power protection systems is very much favoured because of their very long life, commonly ten years. They can therefore be used in remote and inaccessible locations without any attention where routine maintenance and inspection would be very costly. A typical apparatus for which these batteries are very suitable is the outdoor automatic recloser which is a circuit breaker having fault detection circuitry causing it to open on excessive or unbalanced currents. To avoid manual attention in cases where the fault is transitory, the relay circuitry is arranged to make several attempts to reclose the contact mechanism at short intervals, failing which, the mechanism is locked out. The use of $LiSO_2$ batteries to energise both the low power relay circuit and the high power electromagnetic contact mechanism is described in Patent Application No. 9312209. (Ref SWO/4376).

An example of an autorecloser which is manufactured by the Applicants under the designation "OXR" is illustrated in Figure 1. This is a 3-phase recloser, each phase having a tubular insulating casting 1 which contains a vacuum interrupter 3 between HV terminals 5 and 7. The vacuum interrupters 3 are operated by insulating rods 9 which

are driven from a common drive shaft 11. This drive shaft is in turn driven by an electromagnetic actuator 13.

The control circuitry for the recloser, the so-called "protection relay", contains a microprocessor which coordinates the fault detection, automatic protection, recording of fault trips, attempted reclosures and current condition. This relay is housed in a compartment 15 which also contains a low voltage (15V) $LiSO_2$ battery to power the relay (the relay has a high impedance) and a further, high voltage (140V) $LiSO_2$ battery to power the electromagnetic actuator 13, which has a very low impedance. It is the latter battery which is affected by the passivation problems referred to above.

The electromagnetic actuator is shown in Figure 2 (very diagrammatically) and comprises an armature 17 fixedly mounted on a drive shaft 19, the armature and shaft being movable axially within a cylindrical permanent magnet 21, closing coil 23 and opening coil 25. The armature is shown in its open, i.e. downward, position, the switch having been tripped on a fault detection for example.

The permanent magnet 21 has a north pole on its inner cylindrical face and a south pole on its outer face. The resulting flux paths 27 through the armature and upper housing and 29 through the armature and lower housing are shown. In order to change the state of the circuit breaker from the illustrated open position to the closed position, the closing coil 23 is connected to the $LiSO_2$ battery for a short time, e.g. less than 500 milliseconds. The resulting flux 31 is arranged to be in such a direction as to enhance the upper permanent magnet flux 27 and oppose the lower permanent magnet flux 29. The armature therefore moves to reduce the reluctance of the predominant upper flux path. The armature thus moves upwards, taking the drive shaft 11 with it and attempting to close the vacuum interrupter contacts.

A similar operation, but involving the opening coil instead of the closing coil, changes the circuit breaker from the closed to the open position.

The passivation of the anode that occurs in the $LiSO_2$ batteries over the period of months or years that might elapse between faults limits the initial current that can be drawn from the battery. The layer can be considered as a further resistance in series with the load. In the case of the relay circuitry the impedance of this circuitry is very high and the extra internal resistance of the battery (layer) has little effect. In the case

of the electromagnetic operating mechanism however, where the load resistance is very low (approximately 3.5 ohms), the presence of the layer resistance will result in less power being available for the mechanism operation and mal-operation of the auto-recloser. The mechanism has considerable inertia and therefore considerable power is required initially to give it the necessary momentum to achieve full contact closure.

Tests have indicated that if the battery remains on load the layer is gradually broken down and power available to the mechanism increases. However, this method of closing the recloser is not acceptable for two reasons:

(1) as mentioned above high initial power is required to give the necessary momentum, and

(2) if battery power is switched on, as it commonly is, by a field effect transistor, the current carrying capacity is limited and only a short current duration is permissible at the current levels required.

An object of the invention is therefore to alleviate the above difficulties arising from the growth of a passivation layer.

In co-pending British patent application 9415762.5, a method of activating an $LiSO_2$ battery to feed a current pulse to an energising coil of an autorecloser actuator is described, in which, following failure of the application of an energising pulse to the closing coil of the actuator to successfully close the circuit breaker contacts, a series of pulses is applied to the opening coil in order to burn off the passivation layer in the battery. Directly following this operation, a final pulse is applied to the closing coil in order successfully to close the breaker contacts.

In accordance with a first aspect of the invention, there is provided an autorecloser, comprising a timing means, a lithium battery and a dummy load, said timing means being arranged to provide one or more driving pulses to said dummy load from said battery at regular intervals.

Said dummy load may be constituted by an actuator of the autorecloser, said driving pulses being applied to said actuator such that an "opened" or "closed" state of the autorecloser subsisting at the time the pulses are applied is not affected by said pulses.

Said actuator may have separate coils for performing an opening and closing operation on the autorecloser, the dummy load being constituted by an appropriate one of said coils.

Said timing means may comprise a clock means, an interval-setting means and a comparison means, said clock means having an output for providing a signal representative of elapsed time, said interval-setting means having an output for providing a signal representative of a required time interval between successive said one or more pulses, and said comparison means having first and second inputs connected to respective ones of said outputs and having an output for providing a signal indicating that application of said one or more pulses to said dummy load is due.

Said output of said comparison means may be arranged to wake up a microprocessor in the autorecloser, said microprocessor being arranged subsequently to apply said one or more driving pulses to said dummy load.

According to a second aspect of the invention, there is provided a method for depassivating a lithium battery in an autorecloser, the method comprising the application of one or more driving pulses to a dummy load from said battery at regular intervals.

The method may comprise the steps of:

(a) generating continually a first signal representative of elapsed time;

(b) comparing said first signal with a second signal representative of a required value of elapsed time, and, where said first and second signals agree,

(c) applying said one or more driving pulses to said dummy load,

steps (b) and (c) taking place on a regular, periodic basis.

Said dummy load may be constituted by an actuator of the autorecloser.

Said actuator may comprise separate opening and closing coils, and step (c) may comprise the steps of ascertaining if the actuator is in a closed position or in an open position and applying said one or more pulses to said closing coil if the actuator is found to be in a closed position, or to said opening coil if the actuator is found to be in an open position.

In accordance with a third aspect of the invention, there is provided a method for depassivating a lithium battery in an autorecloser comprising an actuator with separate

opening and closing coils and a protection relay having a microprocessor for monitoring the state of a power line to which the autorecloser is connected, for controlling opening and closing operations of the autorecloser and for controlling the depassivation of said lithium battery, the method comprising the steps of:

(a) generating continually a first signal representative of elapsed time;

(b) while the autorecloser is in a "low-power" mode with power withheld from the microprocessor, comparing said first signal with a second signal representative of a required value of elapsed time, and, where said first and second signals agree,

(c) applying power to the microprocessor, the microprocessor then performing the following steps:

(d) ascertaining if a fault exists on a power line to which the autorecloser is connected, and if there is a fault, performing one or more opening operations on the actuator and then returning to step (a), otherwise:

(e) ascertaining if the actuator is in a closed position or in an open position and applying said one or more pulses to said closing coil if the actuator is found to be in a closed position, or to said opening coil if the actuator is found to be in an open position, then returning to step (b).

The following additional steps may be carried out prior to the execution of step (e):

(d′) ascertaining if a communications link has been established between the microprocessor and other devices in the autorecloser, and if such a link has been established, allowing communication to proceed and then returning to step (b), otherwise:

(d″) ascertaining if a primary-control configuration change has been requested, and if such a change has been requested, processing the change in control and then returning to step (b), otherwise executing step (e).

An embodiment of the invention will now be described, by way of example only, with reference to the drawings, of which:

Figure 1 is a schematic diagram of the internal arrangement of a known autorecloser;

Figure 2 is a schematic representation of a magnetic actuator used in the autorecloser of Figure 1 and showing the application of a closing pulse;

Figure 3 is a schematic diagram of some of the component parts of the protection relay of an embodiment of an autorecloser according to one aspect of the present invention, and

Figure 4 is a flow diagram of a depassivation process according to a further aspect of the present invention.

Referring now to Figure 3, the protection relay of an autorecloser according to the invention comprises a microprocessor 30 which is programmed principally to control the opening and closing of the autorecloser contact-breaker contacts connected to associated power lines. This is effected by means of drive pulses appearing at outputs 31 and 32 of microprocessor 30. Output 31 drives a FET 33 which is coupled at its drain to the opening coil 25 of the actuator 13 (see Figure 2), whereas output 32 drives a FET 34 which is coupled at its drain to the closing coil 23 of the actuator 13. The distal end of the coils 23, 25 are connected to the positive pole of a lithium sulphur dioxide battery (not shown) housed in the relay compartment 15, the negative pole of the battery being connected to the sources of the FETs 33, 34.

The microprocessor is programmed to open the contact breaker when a fault condition on a power line 35 is sensed. Sensing is achieved by means of a current transformer 36 feeding a line-current monitor 37. When line-current monitor 37 detects the presence of a fault current on the line 35, a signal is fed to the microprocessor on an input 38, the program of the microprocessor 30 then issuing the necessary "open" command to the coil 25 via the output 31.

Also connected to the microprocessor 30 is a comparator 40. Comparator 40 has a first set of inputs 41 connected to the outputs of a counter/decoder 42 via a bus 43, and second set of inputs 44 connected to the outputs of a set-âlarm decoder 45 via a bus 46. Counter/decoder 42 has a clock input 47 for receiving a clock signal supplied by a clock-signal generator 48. Set-alarm decoder 45 has a set of inputs 49 whereby the setting at which the comparator 40 detects identity between the decoder output signals present on the bus 43 and set-alarm signals present on bus 46 can be adjusted by the user.

Together, the counter-decoder and set-alarm decoder form a clock means and an interval-setting means of a timing means and serve to allow either the opening coil or the closing coil, depending on criteria to be mentioned later, to be pulsed at regular user-defined intervals.

In a preferred embodiment, the counter/decoder takes the form of three counters/decoders (not shown) which are configured to count minutes, days and months, respectively. The minutes counter is arranged to clock the days counter after 60 × 24 minutes have been counted and at the same time reset itself, similarly the days counter is arranged to clock the months counter after an appropriate number of days have elapsed, and then reset itself. In this application, it is not necessary that the exact number of days be counted for a particular month (e.g. 31 days for January, only 28 days for February, except in a leap year, etc.), since all that is required is a regular supply of pulses from the battery at an appropriate periodic interval. The absolute time at which the battery is pulsed is largely immaterial. Thus, the days counter can be set to clock the months counter every 30 days, for example. The set-alarm decoder 45 is then arranged to provide "target" time settings as provided on the user inputs 49, i.e. settings at which the user desires depassivating pulses to be supplied on a regular basis by the battery.

In practice, depending on the conditions of use of the autorecloser, intervals of anything from a few minutes to a few months, or even a year, may be required. Thus, if the recloser is to be placed in an area where it will be operated frequently, or where temperatures do not fall substantially during the year, the alarm settings may be set for pulsing operations to take place only once a year, whereas in areas of consistently low temperatures, a setting of one pulsing operation per week may be necessary.

The sequence of events in the depassivation routine is as illustrated in Figure 4.

When the comparator 40 has detected identity between the actually elapsed time interval and the required time interval, it issues an output signal along a line 50 to a "wake-up" input of the microprocessor 30 (see Figure 3). This signal acts as an alarm "flag" and places the microprocessor 30 in its normal operational mode, upon which the microprocessor is programmed to ascertain the reason why it has been awoken.

To this end, the depassivation routine then continues with a series of questions. Firstly, the microprocessor finds out whether or not it has been woken by the presence of a fault (e.g. short-circuit) on the power line 35 (see Figure 3). If a "line fault" flag has been set by a signal on input 38 of the microprocessor, the microprocessor goes through its normal contact-opening routine, which includes the setting of a "dead-time" before it tries to close the contact-breaker contacts again in the hope that the fault will have gone away by that time. After this routine has been completed, the "sleep" state of the relay is restored. If this flag has not been set, the second question is then asked.

The second question is whether or not a serial data link has been established with the microprocessor. This may be the case where, for example, data relating to protection settings (e.g. typical fault current values) are to be sent to the processor. To check this, the microprocessor tests its serial input, and if it finds that a serial link has been set up, the data communication process is carried out and the "sleep" state restored. If not, the third question is asked, which is whether or not the so-called primary control has been altered. Typically, the recloser will have a number of change-over switches which can be set at will by the user to determine which of a number of primary protection functions that can be carried out by the recloser are to be carried out in a particular application. If one or more of these switch settings have been changed, a signal is sent to the microprocessor flagging the fact. In this part of the overall routine, therefore, the microprocessor checks this flag and, if it is set, the processor executes the demanded process change, after which the "sleep" state is restored. If the flag is not set, the depassivation routine proper is commenced.

The depassivation routine takes the form of ascertaining whether or not the circuit breaker is closed, in which case a pulse is applied to the closing coil 23 and the "sleep" state is restored. (Detection of the operating state of the actuator is effected in an actuator-state detector 52, which sets a "closed" flag as appropriate via an input 53 of the microprocessor 30 (see Figure 3)). If the answer is "no", it is assumed that the circuit breaker is open and a pulse is applied to the opening coil 25, following which the "sleep" state is restored to the relay.

Clearly, instead of first testing if the circuit breaker is closed, it is equally possible to test if it is open, in which case a pulse is sent to the opening coil, failing which a pulse is sent to the closing coil.

Note that by using the appropriate coil as a "dummy" load for the battery, it is ensured that the same value of current is supplied by the battery as would be supplied under normal operational conditions (i.e. contacts actually opening or closing).

While it has been assumed that only one pulse will be applied to the relevant coil every so often, according to the interval setting, it may be advantageous to apply several pulses one after the other in order to maintain adequate depassivation.

Also, the alarm setting function may alternatively be carried out via "jam" inputs of the counters, instead of via a comparison process between an "actual" time signal and a "desired" time signal through a comparator 40. In this case, the timing of a pulse-operation interval corresponds to the time taken for the counters to reach zero from their "jam" inputs, i.e. the comparison process involves the detection of a zero state on the counter outputs, not a finite "desired" state.

The alarm interval setting may be stored in memory in the relay and may be factory-set for specific environments and geographic regions.

CLAIMS

1. An autorecloser, comprising a timing means, a lithium battery and a dummy load, said timing means being arranged to provide one or more driving pulses to said dummy load from said battery at regular intervals.

2. An autorecloser as claimed in Claim 1, in which said dummy load is constituted by an actuator of the autorecloser, said driving pulses being applied to said actuator such that an "opened" or "closed" state of the autorecloser subsisting at the time the pulses are applied is not affected by said pulses.

3. An autorecloser as claimed in Claim 2, in which said actuator has separate coils for performing an opening and closing operation on the autorecloser, the dummy load being constituted by an appropriate one of said coils.

4. An autorecloser as claimed in any one of the preceding claims, in which said timing means comprises a clock means, an interval-setting means and a comparison means, said clock means having an output for providing a signal representative of elapsed time, said interval-setting means having an output for providing a signal representative of a required time interval between successive said one or more pulses, and said comparison means having first and second inputs connected to respective ones of said outputs and having an output for providing a signal indicating that application of said one or more pulses to said dummy load is due.

5. An autorecloser as claimed in Claim 4, in which said output of said comparison means is arranged to wake up a microprocessor in the autorecloser, said microprocessor being arranged subsequently to apply said one or more driving pulses to said dummy load.

6. A method for depassivating a lithium battery in an autorecloser, the method comprising the application of one or more driving pulses to a dummy load from said battery at regular intervals.

7. A method as claimed in Claim 6, comprising the steps of:

(a) generating continually a first signal representative of elapsed time;

(b) comparing said first signal with a second signal representative of a required value of elapsed time, and, where said first and second signals agree,

(c) applying said one or more driving pulses to said dummy load,

steps (b) and (c) taking place on a regular, periodic basis.

8. A method as claimed in Claim 7, in which said dummy load is constituted by an actuator of the autorecloser.

9. A method as claimed in Claim 8, in which said actuator comprises separate opening and closing coils, and step (c) comprises the steps of ascertaining if the actuator is in a closed position or in an open position and applying said one or more pulses to said closing coil if the actuator is found to be in a closed position, or to said opening coil if the actuator is found to be in an open position.

10. A method for depassivating a lithium battery in an autorecloser comprising an actuator with separate opening and closing coils and a protection relay having a microprocessor for monitoring the state of a power line to which the autorecloser is connected, for controlling opening and closing operations of the autorecloser and for controlling the depassivation of said lithium battery, the method comprising the steps of:

(a) generating continually a first signal representative of elapsed time;

(b) while the autorecloser is in a "low-power" mode with power withheld from the microprocessor, comparing said first signal with a second signal representative of a required value of elapsed time, and, where said first and second signals agree,

(c) applying power to the microprocessor, the microprocessor then performing the following steps:

(d) ascertaining if a fault exists on a power line to which the autorecloser is connected, and if there is a fault, performing one or more opening operations on the actuator and then returning to step (a), otherwise:

(e) ascertaining if the actuator is in a closed position or in an open position and applying said one or more pulses to said closing coil if the actuator is found to be in a closed position, or to said opening coil if the actuator is found to be in an open position, then returning to step (b).

11. A method for depassivating a lithium battery as claimed in Claim 10, comprising the following additional steps prior to the execution of step (e):

(d') ascertaining if a communications link has been established between the microprocessor and other devices in the autorecloser, and if such a link has been established, allowing communication to proceed and then returning to step (b), otherwise:

(d'') ascertaining if a primary-control configuration change has been requested, and if such a change has been requested, processing the change in control and then returning to step (b), otherwise executing step (e).

12. An autorecloser substantially as hereinbefore described.

13. A method for depassivating a lithium battery substantially as hereinbefore described.

13

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9519117.7
Relevant Technical Fields (i) UK Cl (Ed.N) H2K (KHE, KJA) (ii) Int Cl (Ed.6) H02H (1/06, 3/06, 3/07)	Search Examiner MR E QUIRK Date of completion of Search 21 DECEMBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1-13

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2269063 A (GEC ALSTHOM LIMITED)	
A	US 4839248 (RAININ INSTRUMENT CO)	

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